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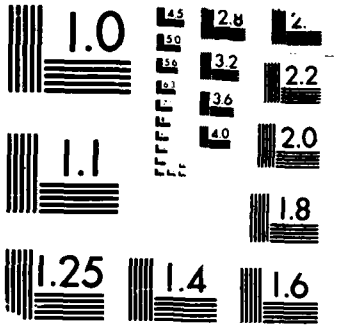

# Statistical Smoothing Methods: Some Practical Aspects

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**Contractor:** University of Bath

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**FIRST PERIODIC REPORT**

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## ADMINISTRATIVE ACTIONS

### Personnel

Dr R. H. Glendinning has been appointed as Research Officer on the project, with effect from 1 October 1986. Dr Glendinning has a strong background in probability theory and computational statistics, and has already been a great asset to the work.

### Equipment

The project now has available to it the almost exclusive use of a SUN 3/160C colour workstation. This has been extremely useful even in these early stages, particularly in the work on image reconstruction and analysis.

## SCIENTIFIC WORK

### Density Estimation

One of the aims of the project is the extension of the existing density estimation methodology in various directions. Among these is the use of density estimation in techniques such as the smoothed bootstrap. A paper [1] on this material has been prepared for publication; in it a criterion is developed for deciding whether smoothing is worth performing in any particular bootstrap situation. This goes some way towards answering the questions raised in Section DE5 of our original proposal, though the question of how much improvement an adaptive kernel approach will make remains for further investigation.

### Nonparametric discriminant analysis

This is an important component part of the methodology which it is hoped will help provide simple robust classification rules for target classification. A considerable amount of progress has already been made on implementing the classification tree approach of Breiman et al and on identifying features of this approach that call for refinement and improvement. Particular such features include the choice of exactly which index one ought to use for growing and pruning the tree, and also the possibility of building a hierarchical bump-hunting approach, the object of which would be to find the best one-dimensional split of the data into clusters at each stage in the tree.

### Image analysis

Work has been performed on several topics in this general area.

### ICM and Annealing

A major task of the Research Officer has been the writing of a suite of programs and algorithms implementing the Besag and Geman approaches to image analysis in order to give a basis for experimentation and improvement. In addition a large simulation study has been carried out on some aspects of these approaches. One particular aspect of interest has been the investigation of the appropriate choice of interaction parameter(s) in the Markov random field model as used in the prior for the images. A theoretical argument demonstrates that an appealing procedure is to weight diagonal neighbours of each pixel by $2^{-\frac{1}{2}}$ the amount used to weight direct neighbours. Such a scheme should produce reconstructions that are are largely unaffected by the way in which the pixel grid is placed on the true underlying image. Preliminary results are now being obtained and they are encouraging.

Another area of interest is the appropriate method for constructing and weighting edge processes. The philosophy used has been to consider the edge process to be a discretized version of a "true" underlying edge process, which arises as the collection of boundaries of a division of the plane into regions. This philosophy yields a logical way of penalizing the various possible configurations of edges, and also gives results of importance when considering irregular patterns of pixels. At present this part of the work is still in the theoretical phase but it is intended to implement it shortly.

**Image Refinement**

Progress has been made on the problem of producing a restored image on a smaller pixel grid than that on which a signal is originally recorded. The computational problem of searching through $2^{n^2}$ possible colourings of a pixel subdivided into $n \times n$ subpixels can be simplified by restricting attention to the case where the boundary has at most one continuous length of each colour, then, identifiable structure in maximum likelihood colourings promises to reduce the search to a manageable scale. More complicated cases must be handled separately but they can be expected to occur infrequently and may well be avoidable by a cleverly defined algorithm in examples where there is a real possibility of substantial refinement.

This work is developing on two fronts. In the first, reconsruction is carried out on a fine pixel grid and differences in colour of neighbouring pixels are penalized through the Gibbs function of the assumed Markov Random Field. The second is the limiting case in which continuously defined regions of colour are allowed and a penalty proportional to the length of boundary between regions of different colour is used. Both methods have generated ideas and possible computational techniques which will be of use in the other.

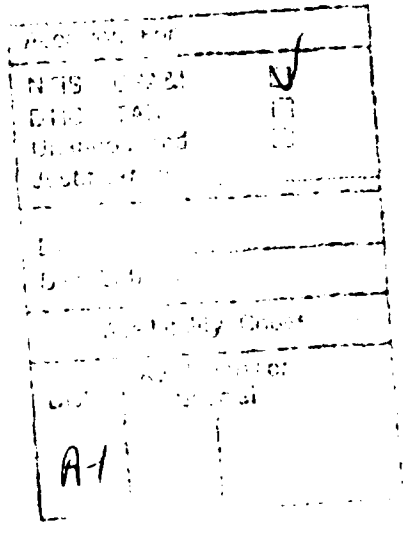
**Indirectly observed images**

Some interesting progress has been made on two of the aspects of the use of the EM algorithm in the reconstruction of indirectly observed images, as described in Section 3 of the original proposal. The idea of discretizing the image into grey levels at every stage of the iteration has been implemented in a particular context, and the results so far obtained are very encouraging. In particular the algorithm has on every case tried terminated after a fairly small number of iterations, and secondly the reconstructions obtained do not suffer from the local granularity that appears if an image of continuous intensity in each pixel is allowed. The colour capabilities of our workstation have been particularly useful in this context.

Another, related, idea is that of smoothing the image by some sort of spatial averaging at each stage in the EM iteration. So far this has only been implemented in the one-dimensional case, and very good results have been obtained there. The algorithm converges much more quickly than in the unsmoothed case, and again it converges to a better result which is free of unwanted rapid local variation. Work is continuing on the extension to the spatial case, and also on theoretical results to explain and expand the practical improvements already evident.

**PUBLICATIONS**

[1] Silverman, B. W. and Young, G. A. The bootstrap: to smooth or not to smooth? *Biometrika*, submitted for publication.



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